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# (54) IMPROVEMENTS IN OR RELATING TO THE MANUFACTURE OF PERMANENT MAGNETS

(71) We, C.I. KASEI COMPANY, LIMITED, a Japanese Body Corporate of (Zip Code; 103), 6, Honcho 2-chome, Nihonbashi, Chuo-ku, Tokyo, Japan, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a method and apparatus for manufacturing a film-formed permanent magnet formed on a surface of paper, cloth, plastics material film or other flexible base material.

Conventional film- or sheet-formed permanent magnets have been manufactured by forming a kneaded mixture of a fine powder of hard magnetic substance with a bonding agent such as plastics material, or rubber into a film about 0.5 mm thick by the extrusion or calender moulding method, and magnetizing such film. This mixture lacks fluidity because the fine powder of magnetic substance is usually hard and also the mixture must contain as much as between 80 and 98 percent by weight of fine powder to attain enough magnetism. Consequently, using such mixture, it is difficult using the extrusion moulding method to manufacture in large quantities permanent magnets having a thickness of 0.5 mm or smaller, because it produces excessive resistance at the extruding die. This offers many problems such as rapid wearing of the extruding die, the cylinder and screw of the extruding machine and the need for great power for extrusion. Use of this mixture in the case of calendar moulding makes it difficult to obtain good surface smoothness. Also, a calendar having great strength is needed. Both methods therefore are unsuited for practical use.

In an attempt to solve the aforesaid problems, some mixtures employ a bonding agent to which some plasticizer or softening agent is added. However, the products made of such mixtures are inferior in bending endurance, cracking resistance and tensile strength. Furthermore, such additional agents are likely to pass into other objects that come into contact with the permanent magnet.

It is an object of this invention to provide a method and apparatus for manufacturing a flexible film-formed permanent magnet having great mechanical strength and magnetism by coating a magnetic film, containing 80 to 98 percent by weight of a fine powder of hard magnetic substance, on a thin sheetlike base material.

Accordingly, in one aspect, the present invention provides a method of manufacturing a film-formed permanent magnet, which method includes; providing a paste containing a solvent and a mixture of a magnetizable material and a bonding agent, the said mixture containing from 80 to 98% by weight of a finely powdered hard magnetic substance as the magnetizable material; depositing a thin film-like coating of the paste on the surface of a thin sheet-like base material; sequentially passing the coating under a plurality of levelling knives arranged in series to level the coating to a uniform thickness and to provide the coating with a smooth surface; magnetizing the finely powdered hard magnetic substance in the levelled coating perpendicular to the surface of the base material; drying the magnetized coating; and roll pressing the dried coating on the base material.

In its second aspect, the present invention provides an apparatus for manufacturing a film-formed permanent magnet, which apparatus comprises; means for depositing on the surface of a thin sheet like base material a thin film-like coating of a paste containing a solvent and a mixture of a magnetizable material and a bonding agent, the said mixture containing from 80 to 98% by weight of a finely powdered hard magnetic substance as the magnetizable material; a plurality of levelling knives arranged in series for levelling the coating to a uniform thickness and providing the coating with a smooth surface; means for passing the coating sequentially under the plurality of levelling knives; means for magnetizing the finely powdered hard magnetic substance

in the levelled coating perpendicular to the surface of the base material; means for drying the magnetized coating; and rolls for pressing the dried coating on the base material.

A film-formed permanent magnet manufactured in accordance with the invention is suitable for a wider variety of uses than the conventional ones, such magnet permitting direct printing of colouring of the reverse surface of the base material, if the material is compatible with such printing or colouring.

For a better understanding of the present invention and to show how the same may be carried into effect, reference will now be made, by way of example, to the accompanying drawings, in which:—

Figure 1 shows a schematic side view showing the overall arrangement of an embodiment of apparatus according to this invention.

Figure 2 shows a schematic side view of the principal parts of the apparatus of Figure 1 on an enlarged scale, and

Figures 3 and 4 show partial side views of different embodiments of apparatus according to this invention.

Referring now to the drawings, Figure 1 shows a flexible base material 1, which is a strip of paper, cloth, plastics material or metallic film, fed off from a rotatable pay-off roll 2 that is supported by a frame of a moulding machine (not shown). The base material 1 is pulled over guide rolls 3 and 4 and a backing rubber roll 5 associated with an arrangement for coating the material 1. The rolls 2, 3, 4 and 5 are all rotatably supported by the frame, whereby the base material can advance to the right as shown in Figure 1. Then, the base material is advanced in a direction indicated by arrow A and taken up by a take-up or winding roll 8 through guide rolls 6 and 7 similarly rotatably supported by the frame.

A mixture 9 containing between 80 and 98 per cent by weight of fine powder of hard magnetic substance, excluding volatile ingredients, which is prepared by kneading into a paste an organic bonding agent such as a polymerizing monomer and polymer, a solvent and fine powder of a hard magnetic substance such as barium ferrite (having a coercive force of 1000 Oersted or more). This paste is placed above the rubber roll 5 and is coated, as a film, on the base material 1 at a rate of from 400 to 800 grams per square meter.

To achieve this coating, doctor knives 10 and 11 are mounted on the frame directly above the rubber roll 5 and a little behind thereof, respectively, with their edges directed toward the centre of the rubber roll 5. The doctor knives 10 and 11 are of such a width as to practically cover the overall width of the base material 1 and their lower ends are shaped like the edge of a knife, with their rear surfaces being sharply tapered. The knives 10 and 11 are disposed so that a uniform space is maintained between their lower edges and the base material 1, as by separate adjustment.

The doctor knives 10 and 11 form a smooth coating or film 12 of uniform thickness by levelling the mixture 9 as supplied on to the base material 1 from a supply means (not shown). By passing the film 12, not yet dried, through a magnetic field formed by magnetizing means 13, the axis of magnetism of the fine powder of magnetic substance is oriented perpendicular to the surface of the base material 1. Then, volatile matter is removed in a dryer 14, through which flows the air in the direction of the arrow B. The coating or film 12 is further pressed between a bright-plated or dull-finished metal roll 15*a* and a rubber roll 15*b* supported by the frame, at a temperature between 30 and 100°C., thereby increasing the adhesion between the film 12 and the base material 1 and finishing the film 12 into a 0.1 to 0.6 mm thick magnetized film 16 with a lustrous surface. After cooling down to room temperature, the product is taken up on the winding roll 8.

The doctor knives 10 and 11 are designed not only to level the paste 9 into a uniform thickness as described above, but also to eliminate bubbles contained in the paste, thereby improving the magnetic characteristics of the magnetized film 16. In starting coating, the thickness of the film 12 is determined by a space $t_1$ between the doctor knife 10 and the base material 1, as shown in Figure 2. The space $t_2$ between the doctor knife 11 and the base material 1 is initially made a little larger than the space $t_1$. Then, an excess of the paste 9, left after the paste has been levelled by the doctor knife 10, forms a bank 17 at the back of the doctor knife 10. This bank 17 is rotated in the direction of the arrow as the base material 1 moves ahead. Then the space $t_2$ is made equal to the space $t_1$, and another bank 18 is formed behind the doctor knife 11, and similarly rotated in the direction of the arrow.

Because the paste 9 is usually highly viscous and contains a large quantity of fine powder of magnetic substance, it is liable to take in bubbles while it is being kneaded. Such bubbles must be thoroughly removed, since they, if contained in the magnetized film 16, make it necessary to use greater magnetizing force for orienting the film 16. The bubbles also bring about a reduction in magnetism after orienting. The rotation of the bank 18 is conducive to holding the mixed bubbles within the bank 18, thereby

preventing them from passing through the space $t_3$. Any residual bubbles which escape through the space $t_2$ are substantially prevented from passing through the space $t_1$ by the revolution of the bank 17. The film 12 is laid by this means, almost perfectly free of bubbles. When the paste 9 contains a large quantity of fine powder of magnetic substance, the surface of the coated film is usually liable to become rough if levelled by a single doctor knife. According to this invention, however, which employs double levelling using a pair of doctor knives 10 and 11, the surface of the coated film 12 becomes very smooth.

Because it contains substantially no bubbles, the coated film 12 requires only a small magnetizing force for orienting the axis of its magnetism as well as for magentizing. Together with the aforesaid excellent surface flatness, this permits the magnetized film 16 to exhibit the maximum magnetic attracting force with respect to its thickness.

Whether the bubbles can be readily eliminated or not usually depends on the composition and other factors of the paste 9. Therefore, a suitable number, not less than two doctor knives may be provided in series, depending on such factors.

Since the film 12 and the magentic orientated film 16 are reinforced with the base material 1, it is possible to orient the axis of magnetism of the film 12 before drying it. Also the magnetic orientated film 16 is firmly stuck to the base material 1, and finished into a smooth lustrous surface by means of the pressing rolls 15*a* and 15*b*. Therefore, the film-formed permanent magnet manufactured in accordance with this invention can not only possess high durability against for example bending and twisting, but also adheres well to the object to be attracted. It can stick fittingly even to a curved surface.

The film-formed permanent magnet produced in accordance with this invention permits direct printing or colouring on the rear surface of the base material 1, assuming of course that the base material is compatible with such printing or colouring. It is also possible to use previously printed base materials. All this widens the range of its use to a very great extent, compared with the film-formed permanent magnets of conventional manufacture.

Comparing the products of the above-described embodiment wherein two doctor knives are disposed in series with another arrangement wherein only one doctor knife is provided, the product of the former has a flat-surface, and uniform in colour, magnetized film; while the product of the latter is roughly surfaced and unevenly coloured, which decreases its value as an article of commerce. Furthermore, according to our experimental results, the fluctuation of magnetic attracting force of the former was only about plus/minus 15 percent, while that of the latter was as high as plus/minus 70 percent. As is evident from this data, the provision of two doctor knives in series achieves an excellent result.

Figure 3 shows an apparatus having a floating knife coater. A base material 1 is tensioned and sent in the direction of the arrow by movable guide roll 20 and adjustable guide roll 21, which rolls are rotatably supported by a frame of a coating machine (not illustrated) in such a manner as to permit adjustment of their horizontal position. Between the guide rolls 20 and 21, the base material 1 is supported by support plates 22 and 23 which are fitted, separately and at the same level, to the frame. Doctor knives 24 and 25 are fixed to the frame, vertical to the base material 1, between the support plate 23 and the guide roll 21 and the support plates 22 and 23, respectively. The doctor knives 24 and 25 have the same structure and function as those of the above-described doctor knives 10 and 11. When the paste 9 supplied at the back of the doctor knife 25 passes under the doctor knives 25 and 24, the base material 1 deflects or bows downward as illustrated in the figure. By adjusting the spaces between the doctor knives 24 and 25 and the base material 1 in the deflected state, a coating or film 12 having a predetermined thickness is formed.

Banks 26 and 27 formed behind the doctor knives 24 and 25 rotate in the direction of the arrows as the base material 1 moves ahead, as in the case of the banks 17 and 18 (see Figure 2) thereby substantially preventing mixed bubbles from entering the film 12. The following processes are similar to those of the above-described embodiment.

Figure 4 shows an embodiment of a knife belt coater. An endless belt 30 is run over rollers 31 rotatably supported by a frame (not shown), with the upper side of the belt 30 being supported by three rollers 33 whose vertical position is adjustable. A base material 1 is tensioned over a lower guide roller 34, said roller 31 on the left and the upper side 32 of the belt 30. By rotating the roller 31 on the right, the base material 1 is carried on the belt 30 in the direction of the arrow.

There are provided three doctor knives 35, 36 and 37 over the upper side 32, and the paste 9 is supplied behind the doctor knife 37. Spaces $t_1$, $t_2$ and $t_3$ are left between the doctor knives 35, 36 and 37 and the base material 1, respectively. At the start, the space $t_1$ is made equal to a desired thickness of a film 12, with the spaces $t_2$ and $t_3$ being made slightly larger than $t_1$.

Then, when a bank 38 has been formed behind the doctor knife 35, the space $t_2$ is made to $t_1$; following which, when a bank 39 has been formed behind the doctor knife 36, the space $t_3$ is made equal to $t_2$. By this means, the coated film 12, levelled three times by the doctor knives 35, 36 and 37, assumes a smooth, flat surface. Also, bubbles are eliminated three times by the rotation of the banks 38, 39 and 40. The following processes are similar to those of the embodiment described previously with reference to Figure 1.

WHAT WE CLAIM IS:—

1. A method of manufacturing a film-formed permanent magnet, which method includes: providing a paste containing a solvent and a mixture of a magnetizable material and a bonding agent, the said mixture containing from 80 to 98% by weight of a finely powdered hard magnetic substance as the magnetizable material; depositing a thin film-like coating of the paste on the surface of a thin sheet-like base material; sequentially passing the coating under a plurality of levelling knives arranged in series to level the coating to a uniform thickness and to provide the coating with a smooth surface; magnetizing the finely powdered hard magnetic substance in the levelled coating perpendicular to the surface of the base material; drying the magnetized coating; and roll pressing the dried coating on the base material.

2. A method according to Claim 1, which includes causing a bank of the paste to accumulate behind each of the levelling knives whereby the bank rotates as the coating moves under the levelling knives, and positioning the levelling knives so that the lower edges thereof are positioned substantially the same distance from the base material.

3. A method according to Claim 2, wherein the levelling knives are positioned adjacent the periphery of a rubber coated roller over which the base material passes.

4. A method according to Claim 2, wherein a pair of support members are positioned beneath the base material at a pair of longitudinally spaced locations, which method includes positioning the two levelling knives so that one knife is disposed directly above the base material at a location between the two support members and the other levelling knife is disposed directly above the base material at a location spaced from a remote edge of one of the support members, so that the two knives engage the coating on the base material and cause the base material to deflect downwardly.

5. A method according to Claim 2, wherein the base material is supported on an upper reach of an endless movable support member, which method includes initially positioning the knives so that they are spaced different distances above the base material to cause a rotatable bank of paste to accumulate behind each knife as the base material moves under the knives, and then adjusting the spacing of the knives so that they are all spaced the same distance above the base material.

6. An apparatus for manufacturing a film-formed permanent magnet, which apparatus comprises; means for depositing on the surface of a thin sheet like base material a thin film-like coating of a paste containing a solvent and a mixture of a magnetizable material and a bonding agent, the said mixture containing from 80 to 98% by weight of a finely powdered hard magnetic substance as the magnetizable material; a plurality of levelling knives arranged in series for levelling the coating to a uniform thickness and providing the coating with a smooth surface; means for passing the coating sequentially under the plurality of levelling knives; means for magentizing the finely powered hard magnetic substance in the levelled coating perpendicular to the surface of the base material; means for drying the magnetized coating; and rolls for pressing the dried coating on the base material.

7. Apparatus according to Claim 6, wherein a bank of the paste is caused to accumulate behind each of the levelling knives whereby the bank rotates as the coating moves under the levelling knives, and the levelling knives are positioned so that the lower edges thereof are positioned substantially the same distance from the base material.

8. An apparatus according to Claim 7, wherein the levelling knives are positioned adjacent the periphery of a rubber coated roller over which the base material passes.

9. An apparatus according to Claim 7, wherein a pair of support members are positioned beneath the base material at a pair of longitudinally spaced locations, the two levelling knives being positioned so that one knife is disposed directly above the base material at a location between the two support members and the other levelling knife disposed directly above the base material at a location spaced from a remote edge of one of the support members, so that the two knives engage the coating on the base material and cause the base material to deflect downwardly.

10. An apparatus according to Claim 7, including an endless movable support member having an upper reach on which said base material is supported, the knives being initially positioned so that they are spaced different distances above the base material to cause a rotatable bank of paste to ac-

cumulate behind each knife as the base material moves under the knives, the spacing of the knives then being adjusted so that they are all spaced the same distance above the base material.

11. An apparatus according to Claim 10, wherein three levelling knives are provided.

12. A method of manufacturing a film-formed permanent magnet, substantially as hereinbefore described with reference to Figures 1 and 2, or Figure 3, or Figure 4 of the accompanying drawings.

13. An apparatus for manufacturing a film-formed permanent magnet, substantially as hereinbefore described with reference to Figures 1 and 2, or Figure 3, or Figure 4 of the accompanying drawings.

14. A film-formed permanent magnet whenever manufactured by the method of any one of Claims 1 to 5 and 12 and/or with the apparatus of any one of Claims 6 to 11 and 13.

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3 SHEETS *This drawing is a reproduction of the Original on a reduced scale*
Sheet 1

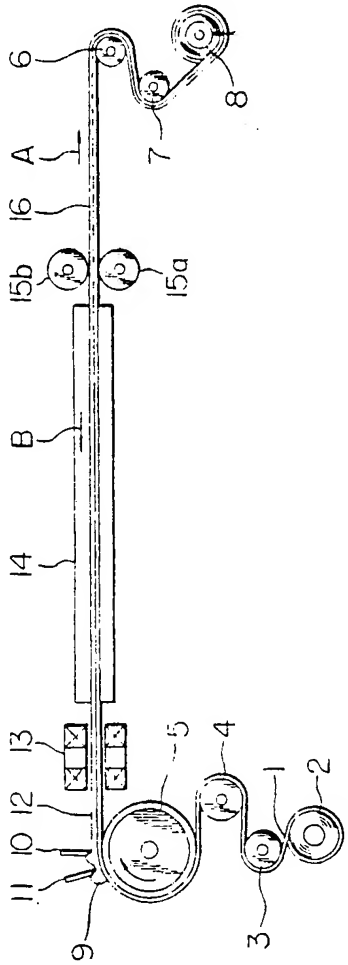


Fig. 1

**Fig. 2**

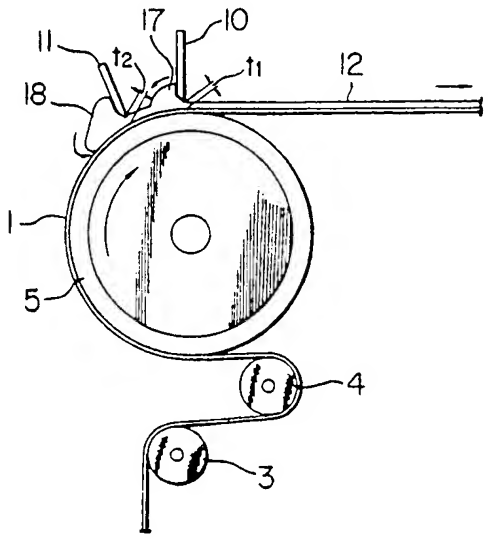

Fig.3

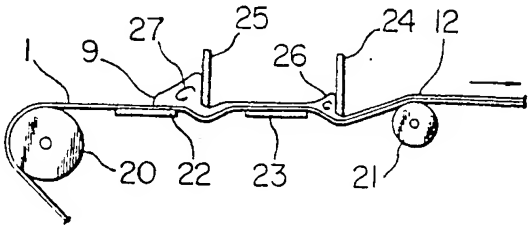
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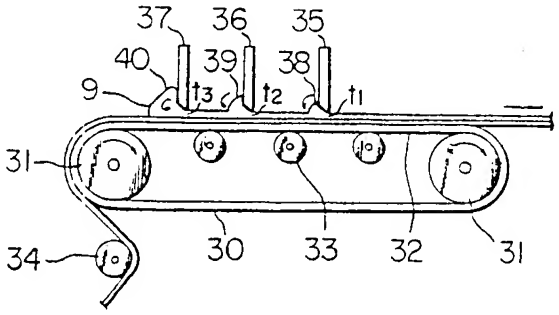
Fig.4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